Consciousness at the Intersection: A Model of Consciousness as the Product of Processing and Biological Need

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Abstract

This paper proposes that consciousness arises neither from pure information processing nor from pure biological need, but from their interaction. We formalize this intuition as $c = p\,b$, where consciousness (c) is the product of processing capacity (p) and biological need (b), and where p declines as a power function of b once need exceeds a homeostatic threshold b_0. The model predicts an inverted-U relationship between need and consciousness, peaking at b_0 — a pattern reminiscent of the Yerkes–Dodson law. We derive six testable predictions, situate the model relative to Integrated Information Theory, Global Workspace Theory, Higher-Order Theories, and homeostatic/free-energy accounts of consciousness, and discuss its convergence with Damasio's work on homeostasis and the enactive/embodied tradition. We also consider two further implications: that consciousness cannot be a fixed, transferable substance, and that building artificial general intelligence may require coupling processing systems to genuine, consequential biological-style needs.

Keywords: consciousness; biological need; information processing; homeostasis; embodied cognition; Yerkes–Dodson law; artificial general intelligence

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1. Introduction

Consciousness is often treated as a fixed, special property — present or absent, and largely independent of the body's condition. This paper takes a different starting point: that consciousness is best understood as the product of two factors, neither of which is sufficient on its own. At one extreme lies pure computation: an algorithm, a machine, that processes information but has no need and nothing at stake. At the other lies pure biological need with minimal processing. Bacteria offer the clearest case: through chemotaxis, they sense chemical gradients and move toward nutrients and away from toxins using a well-characterized molecular signaling pathway, entirely without a nervous system of any kind (Wadhams

& Armitage, 2004). This is genuine, consequential biological need — failure to respond correctly can be lethal to the cell — coupled with a form of signal processing so minimal that essentially no one considers bacteria conscious. This is offered as a working assumption grounded in prevailing intuition rather than as a settled fact; panpsychist positions, which attribute some form of experience to all matter, would reject it, and nothing in the present argument rules such positions out a priori. A related but less clean-cut example is the jellyfish, which lacks a single centralized brain and instead relies on a nerve net and, in some groups, more condensed integrating centers distributed across the body (Satterlie, 2011). Such organisms register sensation and act on need but, plausibly, are not conscious in any sense comparable to organisms with centralized, integrative nervous systems. This example should be read with some caution: recent work has shown that even brainless box jellyfish are capable of associative learning (Bielecki et al., 2023), indicating that "minimal processing" is a matter of degree rather than a strict absence of processing in this case. This trend toward caution is reinforced by recent shifts in the field at large: the 2024 New York Declaration on Animal Consciousness, endorsed by dozens of researchers across disciplines, concluded that current evidence supports at least a realistic possibility of conscious experience across all vertebrates and many invertebrates, including insects — a marked broadening of which nervous systems are treated as plausible candidates for consciousness relative to earlier consensus (Andrews, Birch, Sebo, & Sims, 2024). While cnidarians such as jellyfish are not among the taxa the declaration directly addresses, the direction of this shift counsels against treating the "no consciousness" attribution to minimal nervous systems as more secure than it currently is. The relevant contrast for the present argument is therefore not processing versus no processing, but a system with substantial integrative processing capacity coupled to genuine need (where consciousness is proposed to arise) versus systems that have only one of these two ingredients in significant degree. We suggest that consciousness is found at neither pole, but at their point of intersection.

2. Consciousness Is Not a Fixed Substance

It is unlikely that consciousness is a fixed, special "thing" — an essence that stands apart from the body. If it were, biological events such as a blow to the head or prolonged hunger should not be able to reshape behavior and personality; yet they plainly do. Damage to different regions of the brain can alter personality, memory, judgment, and even a person's sense of identity so profoundly that those around them describe the person as "someone else" — the classic case of Phineas Gage, whose personality changed dramatically after an iron rod passed through his frontal lobe, remains the paradigmatic illustration (Harlow, 1848, 1868). Were consciousness a fixed entity independent of biological machinery, such transformation should not be possible. This malleability of mind under physical intervention sits poorly

with a picture of consciousness as an immutable substance, and fits far more comfortably with a view of consciousness as a dynamic product of a system, not a pre-given essence.

3. Why Consciousness Appears Special: A Perspectival Illusion

What makes consciousness seem so distinctive may be a limitation of our own vantage point rather than a fact about consciousness itself. We cannot picture a world without ourselves in it. We assume, for instance, that a blind person “sees blackness” — but a blind person sees nothing at all, any more than an organ with no visual apparatus could be said to see; there is no blackness and no darkness, only the complete absence of the visual dimension. This is consistent with neuroscientific evidence on blindness: in a sensory-substitution training study, congenitally blind participants — those with no prior visual experience to draw on — showed neither occipital cortex activation nor any visual-like sensation, even when explicitly asked, a category that would have included blackness had it been present. The one exception was a subset of participants with early, but not congenital, blindness, who developed occipital activation through training and reported phosphenes — brief flashes of light; their pre-existing visual system plausibly explains this residual capacity, a distinction that, if anything, sharpens the present argument's relevance to the paradigmatic case of blindness from birth (Ortiz et al., 2011). For a sighted person this absence is nearly impossible to imagine, and that very difficulty is itself the illusion: we mistake the boundary of our imagination for a fact about reality. This point resonates with Nagel's (1974) observation that the subjective character of another creature's experience can be systematically inaccessible from a differently constituted point of view; the present argument extends that observation inward, to our own species' difficulty in imagining its own absences. A related philosophical move — situating a congenitally blind subject against a sighted one to probe the limits of experience — appears in Meehl (1966), though there the gap concerns propositional knowledge of "what red looks like" rather than the phenomenological absence of experience argued here. It should be acknowledged that not all philosophers of perception would accept this framing: theorists sympathetic to a robust sense-datum or "phenomenal blackness" view might hold that the total absence of visual stimulation still constitutes some minimal experiential content, rather than a strict absence of experience; the present argument does not attempt to adjudicate that dispute. Consciousness may be special only to the degree that our own perspective makes it appear so.

A second, complementary reason concerns not the limits of imagination but the texture of experience itself. In living organisms, cognitive processing is almost never experienced in isolation: it is continuously accompanied by a

stream of interoceptive signals — hunger, thirst, respiration, temperature regulation, visceral sensations, and countless other bodily states. The apparent richness of consciousness may therefore partly reflect the persistent integration of cognition with ongoing biological regulation, rather than a special metaphysical property of consciousness itself. This is not a complete account — rich exteroceptive experience, such as a landscape or a piece of music, can feel vivid with only modest interoceptive engagement — but it suggests that at least part of consciousness's apparent specialness reflects the sheer bandwidth of ongoing bodily integration, not a separate ingredient.

4. Need Conscripts Processing

On this view, biological need conscripts processing. Need commandeers the processing system and directs it toward securing what the body requires — food, safety, rest — and it is somewhere in the midst of this service that we take ourselves to be conscious. What we call awareness may be nothing more than the felt texture of processing bent toward need: an inner experience arising precisely because information processing has been placed fully in the service of biological need, viewed only from within that process.

5. Formal Model

The relationship can be stated compactly:

$$c = p\,b$$

$$p = \begin{cases} s \cdot p_0 & \text{if } b \le b_0 \\ s \cdot \dfrac{p_0 \times b_0^{\alpha}}{b^{\alpha}} & \text{if } b > b_0 \end{cases}$$

$$\alpha > 1\,,\; 0 \le s \le 1$$

where c denotes consciousness, p denotes processing, b denotes biological need, and s denotes the availability of the neural substrate capable of supporting processing at all, independent of biological need. Under normal, intact conditions, $s = 1$, and the model reduces to the form used throughout the rest of this paper.

5.1 Processing (p)

The processing term is modulated by two independent factors: whether a neural substrate capable of supporting processing exists at all (s), and the degree to which biological need is drawing on that capacity once it does (the b-dependent decay term below). This separation is necessary because some conditions suppress processing directly, independent of biological need — a case Section 6 returns to.

p does not denote any single cognitive process, but the system's total effective cognitive-processing capacity at a given moment — a quantity arising from the combination of multiple cognitive components, including attention, memory, information integration, reasoning, planning, and related processes:

$$p=\left(p_{attention}, p_{memory}, p_{integration}, p_{reasoning}, p_{planning}, \ldots\right)$$

The exact form of this combination depends on the specific model or empirical data and is left unspecified here; the only assumption is that p increases with the system's overall cognitive-processing capacity.

5.2 Biological Need (b)

Likewise, b does not denote any single biological need, but the total intensity of the system's currently active biological needs — a quantity arising from the combination of needs such as hunger, thirst, oxygen deprivation, sleep need, pain, thermoregulation, and other survival-related drives:

$$b=f\left(b_{hunger}, b_{thirst}, b_{oxygen}, b_{sleep}, b_{pain}, b_{temperature}, \ldots\right)$$

where f is a function reducing these needs to a single quantity, biological need. Its exact form likewise depends on the model or empirical data; the only assumption is that b increases with the total intensity of active biological needs. This need-landscape is not limited to hunger or thirst: it spans the full continuum of homeostatic regulation, including respiration, fatigue, nociception, and visceral sensation alongside the examples already listed, each contributing to b whenever it becomes physiologically pressing.

It should be acknowledged that the relative contribution of each need to b is, at present, unknown, and may not reduce to a single fixed weighting scheme at all: the physiological stakes of, for instance, oxygen deprivation and sleep deprivation differ qualitatively, not merely in degree. One route around this difficulty is to treat b not as a weighted sum but as a dominant-need maximum — $b=max\left(b_{hunger}, b_{thirst}, b_{oxygen}, \ldots\right)$ — reflecting the physiological fact that whichever need is most acute at a given moment tends to dominate behavior and attention, without requiring a fixed exchange rate between qualitatively different needs. Determining the true form of f, and whether it varies across individuals or contexts, is left as an open empirical question; the model's central predictions in Section 7 depend only on b being an increasing function of active need, not on the specific form f takes.

5.3 Why Multiplication, Not Addition

Multiplication is used rather than addition because consciousness is hypothesized to live *between* processing and biological need, not in either

alone. Processing and need — with memory standing out as a particularly central component of processing — are treated not as independent, additive contributors, but as simultaneous, necessary conditions for consciousness: consciousness emerges only where both are present. Multiplication satisfies this requirement directly — if either factor is zero, consciousness is zero as well. A pure computer (b=0) is not conscious no matter how much processing it has, and pure need without processing is not conscious either. Addition does not enforce this constraint. The choice of multiplication is therefore not arbitrary or aesthetic, but follows directly from the model's conceptual assumptions. The same logic extends to substrate availability, introduced below: a system with an intact substrate and genuine need but functionally absent processing capacity (s=0) is, on this model, no more conscious than one with no need at all.

5.3.1 Why the Product Form, Specifically

The requirement that consciousness vanish when either factor is zero rules out additive forms (e.g., a weighted sum $w_1p + w_2b$) but does not, by itself, single out multiplication: several other aggregation functions satisfy the same zero-in-zero-out property, including min(p,b), the geometric mean $\sqrt{(pb)}$, the harmonic mean $2pb/(p+b)$, and the Łukasiewicz t-norm $\max(0, p+b-1)$. A stronger, model-internal argument is available: given the piecewise form of p(b) specified in Section 5.4 — constant at p_0 for $b \leq b_0$ and decaying as $p_0(b_0/b)^\alpha$ for $b > b_0$ — the requirement that consciousness peak exactly at b_0 (Section 6) is not satisfied by every candidate aggregator equally.

Under multiplication, $c(b) = p_0 b$ for $b \leq b_0$, which is strictly increasing, and $c(b) = p_0 b_0^\alpha b^{(1-\alpha)}$ for $b > b_0$, which is strictly decreasing whenever $\alpha > 1$. The peak at b_0 therefore holds for every admissible value of p_0, b_0, and α — it is a structural consequence of the multiplicative form together with $\alpha > 1$, not a coincidence of particular parameter values.

The min(p,b) aggregator's failure is, on closer inspection, conditional in exactly the same sense as the harmonic mean's. For $b \leq b_0$, since $p(b) = p_0$ is constant, $\min(p_0,b)$ equals b whenever $b \leq p_0$ and holds flat at p_0 once b exceeds p_0 — a plateau that arises only when $p_0 < b_0$. For $b > b_0$, $p(b) = p_0 b_0^\alpha / b^\alpha$ decreases continuously from p_0 and crosses b at the unique point $b^{**} = (p_0 b_0^\alpha)^{(1/(1+\alpha))}$, the same closed form as the harmonic mean's b^* without the $1/\alpha$ factor. Because b^{**} is a strictly increasing function of p_0, this crossing point satisfies $b^{**} \leq b_0$ exactly when $p_0 \leq b_0$; in that regime $\min(p(b), b)$ is non-decreasing up to b_0 and strictly decreasing immediately afterward, so its peak coincides with b_0 across the entire region $p_0 \leq b_0$, not merely at the boundary $p_0 = b_0$. Only when $p_0 > b_0$ does $\min(p(b), b)$ continue rising past b_0, since b remains below p(b) until the crossing point b^{**} itself — the regime realized by the illustrative parameters of Section 5.5 ($p_0 \approx 0.8 > b_0 = 0.7$). Because $\alpha > 1$, $b^{**} > b^*$ always, so the minimum's

success region ($p_0 \leq b_0$) is strictly narrower than the harmonic mean's ($p_0 \leq \alpha b_0$): min(p,b) is the more fragile of the two conditionally successful aggregators. Neither, however, matches the product's guarantee, which holds structurally for every admissible p_0, b_0, and α, with no threshold at all.

The harmonic mean's failure is more subtle, and here the exact condition can be stated precisely: for $b > b_0$, the harmonic mean reduces to $c(b) = 2p_0 b_0^{\alpha} \cdot b / (p_0 b_0^{\alpha} + b^{(1+\alpha)})$, whose unique interior critical point occurs at $b^* = (p_0 b_0^{\alpha}/\alpha)^{(1/(1+\alpha))}$. Because b^* is a strictly increasing function of p_0, this critical point satisfies $b^* \leq b_0$ exactly when $p_0 \leq \alpha b_0$ — and whenever the unconstrained critical point falls at or before b_0, the function is monotonically decreasing throughout the valid domain $b > b_0$, so the harmonic mean's global peak coincides with b_0 across the entire region $p_0 \leq \alpha b_0$, not merely at the single point $p_0 = \alpha b_0$. Only when $p_0 > \alpha b_0$ does the peak shift strictly past b_0, to b^* itself. The harmonic mean's failure is therefore conditional rather than near-universal: it reproduces the product's peak location whenever processing capacity is not too large relative to α times the need threshold — a condition satisfied, for instance, by the illustrative parameters used in Section 5.5 ($p_0 \approx 0.8 < \alpha b_0 = 1.4$) — and departs from it only outside that region. What distinguishes the product is not that rival aggregators almost never succeed, but that the product is the only member of this family whose peak sits at b_0 unconditionally, for every admissible p_0, b_0, and α, with no dependence on their relative magnitudes.

The geometric mean is a partial exception, and is best understood not as failing the peak criterion but as offering nothing beyond it. Because $\sqrt{(pb)}$ is a strictly increasing transformation of pb, it is maximized at exactly the same point as the product and therefore also peaks at b_0 for every admissible parameter value, exactly as multiplication does. The geometric mean is ruled out on grounds of parsimony rather than inconsistency: since it shares the product's argmax and differs from it only by a monotonic square-root transform, adopting it in place of the product would introduce an additional nonlinearity into every downstream prediction without changing which point is identified as the peak or adding any independent predictive content. Multiplication is retained as the simpler member of an equivalence class of aggregators that all satisfy the model's peak requirement, rather than as the unique aggregator capable of doing so.

A fourth candidate, the Łukasiewicz t-norm $c(b) = \max(0, p+b-1)$, fails more decisively than either min or the harmonic mean. For $b \leq b_0$, where $p(b) = p_0$ is constant, $c(b) = \max(0, p_0+b-1)$ is strictly increasing in b. For $b > b_0$, $c(b) = p_0(b_0/b)^{\alpha} + b - 1$ is convex rather than concave, so its unique interior critical point is a minimum, not a maximum; more importantly, because $p_0(b_0/b)^{\alpha} \to 0$ as $b \to \infty$ while b itself grows without bound, $c(b) \to \infty$ as need increases without limit. Rather than merely mislocating the peak, the Łukasiewicz aggregator predicts no peak at all — consciousness would increase indefinitely under extreme need, directly contradicting Prediction

2 (Section 7). It is also worth noting that the Łukasiewicz t-norm is conventionally defined for arguments restricted to [0,1]; applying it to the unrestricted range $b > b_0$ already stretches the aggregator beyond its native domain, which is itself grounds for caution independent of the peak-location argument above.

Table 2 summarizes how each candidate aggregator fares against the two structural requirements used throughout this section — vanishing when either factor is zero, and placing the model's peak structurally at b_0.

Aggregator	**Zero-in-zero-out**	**Peak structurally at b_0**	**Issue**
min(p,b)	✓	✓ if $p_0 \le b_0$; ✗ if $p_0 > b_0$	Matches product's peak throughout $p_0 \le b_0$; peak shifts to $b^{**}=(p_0 b_0^{\alpha})^{(1/(1+\alpha))}$ only when $p_0 > b_0$
Harmonic mean	✓	✓ if $p_0 \le \alpha b_0$; ✗ if $p_0 > \alpha b_0$	Matches the product's peak throughout $p_0 \le \alpha b_0$; peak shifts past b_0 only when $p_0 > \alpha b_0$
Łukasiewicz t-norm	✓	✗ (no peak at all)	$c(b) \to \infty$ as $b \to \infty$; directly contradicts Prediction 2
Geometric mean	✓	✓	Adds a nonlinearity with no independent predictive content
Product (adopted)	✓	✓	None

Since $\alpha > 1$ implies $\alpha b_0 > b_0$, the two conditionally successful aggregators can be ranked by robustness: the harmonic mean's success region strictly contains the minimum's, while the product's success region is unconditional, holding for every admissible p_0, b_0, and α.

5.4 The Decay Function

While need remains at or below equilibrium ($b \leq b_0$), processing holds at its baseline level p_0. Once need rises past the threshold b_0 — through hunger, sleep deprivation, or any other form of deprivation — processing declines, falling off as a power function. The parameter α sets the steepness of this decline: the larger α, the faster processing collapses under mounting need.

The formulation above treats b_0 as a single, fixed threshold shared across all need types, but this is almost certainly an idealization. Different needs plausibly have different thresholds, and perhaps even different qualitative profiles. Pain, for instance, has a well-documented capacity to interrupt and capture attention even at low intensity, redirecting processing toward the source of threat rather than simply depleting it (Eccleston & Crombez, 1999) — behavior consistent with a comparatively high b_0 for pain specifically, within which mild-to-moderate pain could plausibly sharpen rather than degrade processing, with degradation setting in only once pain becomes severe enough to overwhelm this attentional response. Hunger and sleep pressure, by contrast, may have a much lower effective b_0, such that processing begins to decline almost as soon as either need becomes active, with little or no initial rising phase. If so, b_0 would be better written as a function of need type rather than as a single constant, with the shape of this function — including whether some needs show a genuine rising phase in p rather than the flat plateau assumed above — left as an open empirical question. This refinement does not alter the core structure of the model, which continues to hold for any single, dominant need considered in isolation; it bears specifically on how the model should be applied when comparing across different need types. We flag this as a direction for future development rather than a settled feature of the present formulation, since we are not aware of direct evidence establishing need-specific values of b_0.

5.5 Toward Operationalization

Although p and b are left formally unspecified in this initial model, both admit plausible operational proxies. Processing capacity (p) could be indexed through standardized cognitive tasks (e.g., n-back tasks for working memory, sustained-attention paradigms) or through EEG/fMRI-derived complexity measures such as the Lempel–Ziv complexity metrics used in the integrated-information literature. Biological need (b) could be indexed through physiological markers such as cortisol for stress, blood glucose for hunger, or hours of prior wakefulness for sleep pressure. Validating these proxies against the model's predictions in Section 7 is left for future empirical work.

To make this concrete, consider a purely illustrative numerical case — not a validated measurement protocol, but a demonstration that the model yields a computable output once p and b are operationalized. Suppose each

component is first normalized to a 0–1 scale relative to its own physiological or task-based reference range. Using the dominant-need maximum proposed above, an individual who is mildly hungry (0.3), not thirsty (0.1), and significantly sleep-deprived after 30 hours awake (0.7) would have max(0.3, 0.1, 0.7) = 0.7, so b=0.7. Taking an unweighted mean of normalized attention, working-memory, and reasoning scores (0.80, 0.75, and 0.85) and setting b_0=0.7 so that this individual sits exactly at threshold, p=p_0≈0.80, giving c=pb≈0.56 in arbitrary units. If the same individual remains awake a further ten hours (b≈0.85, now past threshold) with α=2, processing falls to p≈0.54, giving c≈0.46 — a measurable decline consistent with Prediction 2 in Section 7. These particular normalization choices are offered only to show that the model, once minimally operationalized, generates comparative, falsifiable numbers; establishing that they track anything real is exactly the empirical work called for above.

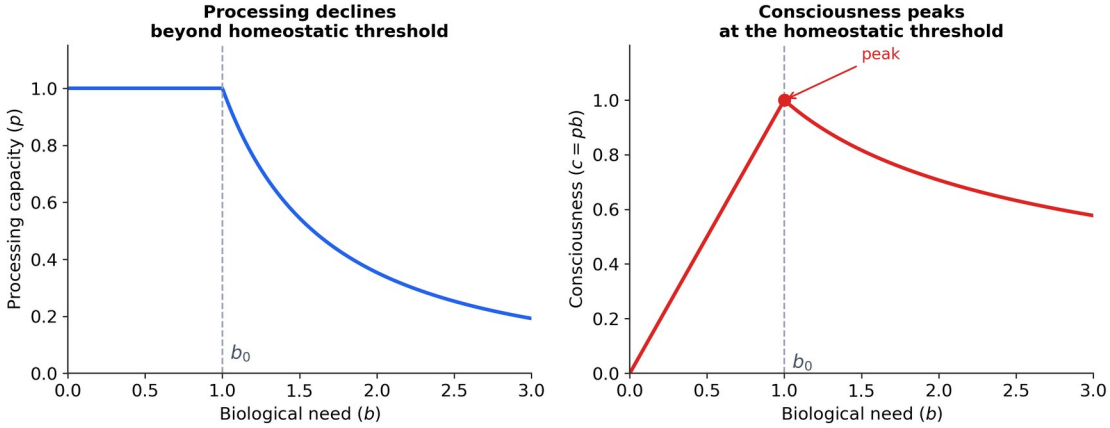
5.6 Scope and Interpretation

One respect in which the multiplicative form might seem underspecified is worth clarifying directly. The model does not require that the processing captured by p be, moment to moment, specifically about the need captured by b — a person absorbed in solving an unrelated problem while hungry is not thereby excluded from consciousness on this account. What the model requires is coarser: that p and b be properties of the same system, and that this system's processing operate within an organism for which something is genuinely at stake — not that each individual computation carry that need as its topic. This is not a gap in the account but follows directly from Section 4: need biases and recruits a system's processing capacity in general, over the timescale of an organism's ongoing self-maintenance, rather than dictating the topic of each specific act of processing. Multiplication is doing substantive work regardless of this distinction: it is what rules out consciousness in a system with extensive processing but no stakes at all, and in a system with genuine stakes but negligible processing capacity, which remains the paper's central claim. Second, b in practice may rarely reach exactly zero in an awake organism: continuous, low-level interoceptive and somatosensory contact with the environment — ambient temperature, airflow on skin, posture, background visceral tone — plausibly keeps b bounded away from zero even in the absence of any acute, salient need. This is consistent with the account, since it predicts a correspondingly low but non-zero c rather than a lapse into unconsciousness; it is noted here because it means b, as operationalized in Section 5.5, should be expected to have a non-zero floor even in ordinary, comfortable conditions, rather than approaching zero as the acute-need examples there might suggest.

6. Implication: A Peak at the Threshold

Because consciousness vanishes both at zero need and where need grows large enough to overwhelm processing, it reaches its maximum not at either

extreme, but within an intermediate band of need — a peak that sits exactly at b_0. Put differently, consciousness requires enough need for something to be at stake, but not so much that it overwhelms processing.



Processing capacity and consciousness level as a function of biological need

Figure 1. Left: processing capacity declines once biological need crosses the threshold b_0. Right: this decline, combined with the linear rise in need, produces a peak in consciousness exactly at b_0.

As discussed below, this inverted-U shape has a well-known relative in psychology.

The model as formulated separates two independent ways in which processing can be limited: through the substrate-availability term s, and through the need-dependent decay captured by b. This distinction directly addresses conditions such as general anesthesia, coma, or severe traumatic brain injury, in which processing itself — not biological need — is suppressed. General anesthesia, for instance, does not eliminate the organism's biological needs — thermoregulation, metabolic demand, and nociceptive processing continue at some level — but it directly suppresses the neural machinery underlying processing itself. This is captured by $s \to 0$ rather than by any change in b: since p is itself defined in terms of s above, $s \to 0$ drives $p \to 0$ directly, and, on the present model, $c = pb$, so this in turn drives $c \to 0$ regardless of the value of b, exactly as observed clinically. Because s is continuous rather than binary, the model further predicts that partial suppression of the substrate — as in light versus deep sedation — should produce a graded, not all-or-none, decline in c, a prediction distinct from, and additional to, the need-driven predictions of Section 7. Whether s ever reaches exactly zero under anesthesia, or only a very low value, remains an open empirical question, one the model shares with other processing-based accounts of consciousness.

7. Testable Predictions

If this formulation is correct, it yields at least six testable predictions:

1. Consciousness should decrease as biological need approaches zero.
2. Consciousness should also decrease under extreme biological need.
3. Task performance that depends on the processing resources indexed by p — as distinct from the degree of consciousness itself, which this model does not yet operationalize independently of p and b — should peak near the homeostatic set point, mirroring the Yerkes–Dodson pattern discussed in Section 11.
4. Artificial systems in which need-like variables such as hunger, pain, or reward function merely as abstract inputs to be recognized or optimized, without persistently and continuously constraining the system's ongoing processing, priorities, and resource allocation, should not, on this model, exhibit consciousness regardless of the sophistication of their information processing; consciousness requires functionally equivalent homeostatic mechanisms that generate genuine internal constraints, not merely represented ones.
5. Unlike theories that ground consciousness in structural integration alone (e.g., IIT), the present model predicts that a system with high informational integration but no genuine, consequential internal need — for instance, a highly integrated simulation with no true homeostatic stakes — should exhibit no consciousness regardless of its integration measure.
6. Because substrate availability (s) is continuous, depth of anesthesia or sedation should produce a graded decline in consciousness tracking the degree of substrate suppression, not an abrupt switch at a single threshold.

8. Consciousness as Process, Not Transferable Substance

The model carries an implication beyond biology. If consciousness arises from the interaction of processing — of which memory is a central component — and biological need, then “consciousness” is not an independent object or substance that could, in principle, be transferred like a file from one brain to another. What exists is only the momentary state of this interaction, a state that changes the instant either component changes. On this view, consciousness is better understood as an ongoing process than as an object that could be stored or relocated.

9. A Question for Artificial Intelligence

This formulation also raises a concrete question about artificial minds. Section 1 characterized pure computation as processing with no need and nothing at stake; on the present model, any route to conscious AI, or artificial general intelligence (AGI), would require closing precisely this gap

— engineering a system for which certain internal states function as genuine, consequential stakes in its own continued operation, rather than as inputs merely labeled hunger, pain, or reward. A standard objection applies here: even a system engineered this way would not, by that fact alone, demonstrate that it feels anything, as opposed to merely processing such states as inputs. The present model does not resolve this by fiat, but it does narrow the empirical question: on this account, the relevant test is not whether a system reports pain, but whether a need-like variable functions as a genuine, consequential constraint on the system's ongoing processing and behavior, rather than as an input the system merely represents and can disregard without cost. This is a necessary condition on the present model, not a sufficient one: a system could satisfy it and still raise the classic philosophical "zombie" worry, exhibiting every functional hallmark of felt need — approach and avoidance behavior, self-report, autonomic-like regulation — without there being anything it is like to be that system (Chalmers, 1996). The present proposal offers a sharper empirical criterion than purely functional or behavioral tests provide, but, like any theory of consciousness grounded in functional or structural properties, it cannot by itself dissolve this residual philosophical question.

This question is not merely speculative. Man and Damasio (2019) have already proposed a concrete architecture along related lines: machines built with homeostatic regulation — maintaining internal "viability" ranges akin to biological self-preservation — as a route to systems that evaluate their own states in a manner functionally analogous to feeling, rather than machines that merely optimize an externally imposed reward signal. The present model converges with this proposal on what counts as the relevant second ingredient: genuine, consequential regulation, not simulated reward.

This requirement constrains how such regulation must be implemented. Programming a system to recognize hunger, pain, or reward as labeled, abstract variables — inputs the system represents and can act on, but which carry no cost to disregard — would not satisfy it. The variables must instead function as genuine internal constraints that shape the system's ongoing processing, priorities, and decision-making: in biological organisms, states such as hunger, thirst, fatigue, pain, and thermoregulation are not signals reported to a central monitor, but continuous pressures that shape cognition and behavior in the service of survival. An artificial system consistent with the present theory would require functionally equivalent mechanisms — not a literal reproduction of hormones or metabolism, but persistent internal states that dynamically modulate processing and create genuine trade-offs among competing goals, resource preservation, and self-maintenance. On this view, increasing computational power or model complexity is not sufficient for consciousness: absent persistent coupling between cognition and internally generated, consequential regulation, artificial systems should remain highly capable information processors rather than conscious agents.

10. Relation to Existing Theories of Consciousness

The present proposal is best understood not as a rival to the major contemporary theories of consciousness, but as an account that foregrounds a factor — biological need — that those theories treat only implicitly or not at all.

Integrated Information Theory (IIT), developed by Tononi and colleagues, holds that consciousness corresponds to the amount of integrated information (Φ) a system generates through its causal structure, independent of whether that system is biological. IIT specifies a structural condition for consciousness but does not itself require that the system have anything biologically at stake; on IIT, a sufficiently integrated non-biological substrate could in principle be conscious. The present model differs by making biological need, not integration structure, the second necessary factor, and by predicting that need's absence — not merely low integration — is sufficient to abolish consciousness. It is worth noting that IIT's testability has itself become a matter of open dispute within the field, with a 2023 open letter signed by over 100 researchers arguing that its core claims remain empirically unfalsifiable (Fleming et al., 2023) — a criticism the present, explicitly falsifiable predictions in Section 7 are intended to avoid.

Global Workspace Theory (GWT), from Baars and later Dehaene, holds that a mental content becomes conscious when it is broadcast from local, encapsulated processes into a "global workspace" accessible to multiple cognitive subsystems. GWT specifies an architectural condition — broadcast and access — rather than a motivational one. The present model is compatible with GWT's architecture but adds a claim GWT does not make: that the workspace's contents become conscious specifically because they are recruited in the service of biological need, not merely because they are broadcast.

Higher-Order Theories (HOT) (Rosenthal, 2005) hold that a mental state is conscious when the system has a further, higher-order representation of that state. Like IIT, HOT specifies a representational condition without reference to biological stakes; a system could in principle have higher-order representations of purely simulated, need-free states.

Homeostatic and Free-Energy Accounts (Solms & Friston; Panksepp) occupy the closest territory to the present proposal and warrant more direct engagement than a passing note of convergence. Solms and Friston (2018), elaborating Friston's free-energy principle, argue that consciousness is the subjective aspect of an organism's ongoing regulation of homeostatic viability: affect is the felt quality of prediction error relative to homeostatic set points, arising primarily from upper-brainstem structures rather than the cortex (see also Solms, 2021). Panksepp's (1998) affective neuroscience

program independently converges on the same subcortical, need-based territory. Both share the present model's central commitment that pure information processing without biological stakes is insufficient for consciousness. This general thesis — that biological need is a necessary condition for consciousness — was developed independently; the convergence with Solms and Friston's and Panksepp's accounts noted here was recognized only after the present model had already taken shape.

Where the present model differs is in the necessity, not merely the sufficiency, of processing. Solms's strongest evidence — behavioral reports of emotional responsiveness in children with hydranencephaly, who lack most or all of the cerebral cortex yet remain awake and show affective reactions to their environment (Merker, 2007) — is typically read as showing that consciousness can arise from homeostatic regulation with minimal cortical processing, in tension with this model's claim that p must be substantially above zero for c to be non-negligible. Two responses are available, and the present model does not yet adjudicate between them. First, the brainstem structures implicated in these cases are not processing-free — they integrate and prioritize competing homeostatic signals, which Solms and Friston's own account depends on — so the relevant question is whether p is low but non-zero in these cases rather than strictly zero, in which case a correspondingly diminished but non-zero c is exactly what the model predicts, not a counterexample to it. Second, this evidence and Solms's inference from it are themselves contested: Berlin (2013) argues that the hydranencephaly data conflate “consciousness as such” (wakefulness) with the “content of consciousness” (what, if anything, is being represented), and that the same data are compatible with the more conservative reading that these children are aroused but have little or no reportable content — a distinction the present model, which treats c as a single graded quantity reaching exactly zero only when p or b is zero, was not built to draw, but could be extended to accommodate by relating p specifically to content-bearing processing rather than to arousal. Adjudicating this dispute is beyond the present paper's scope, but the tension is flagged rather than avoided: the present model's commitment to processing as jointly necessary with need is a more conservative, more easily falsified claim than Solms and Friston's brainstem-first account, and it inherits an open empirical question the free-energy account is also still working through.

Theory	**Core Condition for Consciousness**	**Contrast with the Present Model**
IIT	Integrated information (Φ) generated by a system’s causal structure	No requirement that the system have anything biologically at stake; the

Theory	Core Condition for Consciousness	Contrast with the Present Model
		present model makes need, not integration, necessary
GWT	Broadcast of content into a global workspace accessible to multiple subsystems	Architectural condition only; the present model adds that broadcast content becomes conscious specifically through service to biological need
HOT	A further, higher-order representation of a given mental state	Representational condition only; could in principle apply to higher-order representations of purely simulated, need-free states
Solms & Friston / Panksepp	Consciousness as the subjective aspect of homeostatic/free-energy regulation, generated primarily by brainstem affect systems	Treats substantial cortical processing as contributing content but not required for basic affective consciousness; the present model treats processing as jointly necessary with need — a more conservative, more easily falsified claim

Against this background, the present model's distinctive claim relative to IIT, GWT, and HOT is that none of these structural or representational conditions is sufficient by itself — that whatever integration, broadcast, or higher-order representation is doing, it becomes conscious specifically when it is in the service of genuine biological need. Relative to the homeostatic and free-energy accounts, the distinctive claim runs the other direction: that substantial processing capacity is necessary, not merely that homeostatic regulation is present. This claim is, in principle, independent of and testable against the structural claims of IIT, GWT, and HOT, and against the brainstem-first claims of Solms and Friston.

It should also be stated plainly what this model does not claim. The present proposal specifies a condition under which consciousness is hypothesized to arise; it does not attempt to explain why such a conjunction of processing and need should be accompanied by subjective experience at all — the explanatory gap that constitutes the hard problem of consciousness (Chalmers, 1995) remains untouched by this account. The model's ambitions are accordingly modest: it aims to specify when consciousness occurs, not why physical processes should be accompanied by experience in the first place.

Experience-oriented language used elsewhere in this paper — such as “felt texture” (Section 4) or “subjective experience” (Section 12) — should be read as a working, provisional description of the phenomenon the model targets, not as a claim that the explanatory gap noted above has been closed.

11. Convergence with Existing Research

This intuition — that consciousness is inseparable from the body and its needs — is not unique to the present account. It aligns with several strands of contemporary consciousness science, including Antonio Damasio’s work on the role of homeostasis and feeling (Damasio, 1999), and the enactive/embodied tradition in cognitive science (Varela, Thompson, & Rosch, 1991). More recent work in this tradition has pressed the point further: Ziemke (2016) argues that embodied cognition research has, on the whole, underweighted the role of the living body’s own homeostatic and allostatic self-regulation in grounding cognition, relative to its emphasis on sensorimotor interaction with the environment — a gap the present model’s emphasis on biological need directly addresses. The resulting inverted-U curve is also a relative of the Yerkes–Dodson law in psychology (Yerkes & Dodson, 1908), which holds that performance improves with arousal only up to a point, after which further arousal degrades it — though it should be noted that the original Yerkes–Dodson data, based on a small number of mice, has since been re-examined and its status as a general “law” questioned (see, e.g., recent critical re-analyses in *Trends in Cognitive Sciences*). This convergence is not a weakness of the account; it suggests that the argument, developed independently and from first principles, has arrived at a direction that serious researchers have taken by other routes.

12. Conclusion

What has been presented here is a developing theoretical proposal, not a settled claim. Its structure, however, is simple: consciousness is found neither in pure processing nor in pure biological need, but in their product — precisely where a processing system has something genuinely at stake. This simple picture helps make sense of the lived experience of biological minds, situates itself against the major structural theories of consciousness,

and offers a concrete, testable route for probing consciousness in machines. Consciousness, on this view, is not something added to the brain as a separate entity; it is the subjective experience that emerges from the continuous interaction between cognitive processing and biological regulation.

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